

CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-96

December 11, 1980

1. Name of faults

SE segments of Sargent and Castro faults.

2. Location of faults

San Felipe, Chittenden, Watsonville East, Hollister, and Mt. Madonna 7.5-minute quadrangles, Santa Clara and San Benito Counties (figure 1).

3. Reason for evaluation

Part of 10-year program (Hart, 1980) and request from Santa Clara County.

4. References

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#### 5. Review of available data, air photo interpretation, and field checking.

Faults that are evaluated in this Fault Evaluation Report (FER) include the southeast segments of the Sargent fault and Castro fault, which will be collectively referred to as the Sargent fault zone (figure 1).

SARGENT FAULT ZONE

The Sargent fault zone extends northwest for about 34 miles between the Calaveras fault zone to the southeast and the San Andreas fault zone to the northwest (figure 1). The southernmost 16 miles of the Sargent fault zone from Highway 152 (Hecker Pass Highway) southeast to a point north of Hollister will be discussed in this FER (figures 2, 3). The Castro fault will be considered to be a segment of the Sargent fault zone in this FER.

Northwest of the FER study area the Sargent fault zone is characterized primarily by southwest-dipping reverse faults. In the Mt. Madonna State Park area (northwest of Highway 152), a very complex pattern of imbricate thrust faults marks the fault zone. In the FER study area the Sargent fault zone is characterized by a complex zone of discontinuous, multiple fault traces that generally trend northwest. Deposits of Holocene sediments are sparse along the trend of the Sargent fault zone and Holocene geomorphic surfaces are continually modified by ongoing erosion and downslope movement. Recent faulting locally may occur along one or more of the "older" faults that are numerous in Mesozoic and Tertiary bedrock that underlie the study area (McLaughlin, 1974).

Displacement on the Sargent fault zone has been predominantly high-angle reverse in the study area during most of pre-late Pleistocene (?) time (Allen, 1946; McLaughlin, 1973, 1974). High-angle right-lateral strike-slip offset characterizes the fault zone in recent geologic time (Allen, 1946; McLaughlin, 1974; W.H.K. Lee, p.c. 1989). Evidence of offset with a significant vertical component is located at the southeastern end of the Sargent fault zone in the San Felipe quadrangle (Rogers, in press; Dibblee, 1975). Allen (1946) reported that movement along the Sargent fault has been vertical to near vertical in a reverse sense, northeast side up. He postulated

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that displacement of at least 3000 feet had occurred, with Franciscan rocks on the northeast thrust against "Monterey" sandstone on the southwest. However, McLaughlin (1971, 1973; McLaughlin and others, 1971) reports that stratigraphic relationships indicate reverse faulting with the southwest side up.

The Sargent fault was first mapped in detail by Allen (1946) (figure 2). Allen observed a "soil ridge 2 feet high" near Whitehurst Road in the northeastern corner of the Watsonville East 7.5-minute quadrangle. Allen assumed this soil ridge to be fault related and thus indicative of recent faulting. The 2-foot high soil ridge could not be located by this writer during a brief field check of the area in November 1979. McLaughlin was never able to locate the soil ridge and assumes that it has been destroyed by erosion (personal communication, 1979).

Farther southeast along the trend of the Sargent fault Allen shows a fault branching more easterly from the main trace in the southeast corner of section 22, T11S, R3E (figure 2b). This branch of the Sargent fault (north branch Sargent fault) displays geomorphic evidence of Holocene faulting (closed depression, beheaded drainage, linear trough) in sections 23 and 25, T11S, R3E (figure 3b). Allen reports that from 250 to 300 feet of right-lateral strike-slip displacement has occurred along this branch of the Sargent fault (figure 3b).

In the first canyon north of Tar Creek (section 31, T11S, R4E) Allen shows an east-trending fault branching from the south branch Sargent fault (figure 2b). Allen does not show this fault as cutting Pleistocene terrace deposits near the eastern end of Tar Creek (figure 2b). No evidence of

recent faulting in this area could be found by this writer, based on interpretation of air photos and brief field checking. The south branch Sargent fault from section 26, T11S, R3E southeast to the east edge of the Chittenden quadrangle does not have evidence of Holocene surface faulting, based on air photo interpretation and field checking by this writer.

About 1/2 mile of right-lateral strike-slip displacement of Franciscan rock units has occurred along the Castro fault (Allen, 1946). McLaughlin (1973) states that evidence for strike-slip displacement is equivocal along the portion of the Castro fault from Hecker Pass Highway southeast for about 2 miles. Stratigraphic relationships may also be explained by reverse faulting, south side up.

Recent surface faulting on the Castro fault is indicated by Allen (1946). He mapped a parallel fault trace about 1500 feet south of the main trace Castro fault. Allen observed a 10-foot high north-facing scarp in a saddle in the vicinity of hill 1743 (figure 2a). A subtle tonal lineament about 1000 feet long can be observed on air photos (USGS, 1963) within the location referred to by Allen (figure 2a, 3a). The tonal lineament may be a north-facing scarp, but is subtle and should be field verified, if time permits. Evidence against Holocene faulting on the Castro fault can be found just southeast of Hecker Pass Highway where Pleistocene terrace deposits are not cut by the fault (McLaughlin, 1971, 1973, 1979, p.c.) (figure 2a). Allen's southerly trace of the Castro fault is not shown by Dibblee and Brabb (1978).

McLaughlin (1971) mapped in detail a segment of the Sargent fault zone on the Mt. Madonna 7.5-minute quadrangle and for about 2 miles southeast onto the Watsonville East quadrangle (figure 2a). The Sargent fault

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mapped by McLaughlin is complex, with multiple, discontinuous traces. Near Whitehurst Road, Holocene sediments in the bed of a stream were reported by McLaughlin (1973, 1974) to be vertically offset 1.3 feet, southwest side up (figure 2a). McLaughlin differentiated this step in the streambed from other erosional steps on the basis of spring mineralization near the step and the apparent alignment with other geomorphic features indicating Holocene faulting. However, McLaughlin does not now believe this step to be necessarily fault related (McLaughlin, 1979, p.c.). Many steps along the streambed were observed by this writer during a brief field check in November 1979, but all seemed to be the result of stream processes. Fault related geomorphic features northwest of the north-south power lines are very weak and evidence of faulting generally can be found only in the exposed bedrock in stream gullies and canyons. Geomorphic features indicating recent faulting, such as offset drainage, scarps, benches, and linear drainages, can be followed for about 1 1/2 miles southeast of the power lines (figure 3a).

Dibblee and Brabb (1978) mapped the geology of the Watsonville East and Chittenden 7.5-minute quadrangles (figure 2a, 2b). Their fault traces differ primarily with Allen's (1946) traces along the northwestern end of the Sargent fault where more complex traces have been identified, along Allen's southerly trace of the Castro fault <sup>h</sup>where Dibblee and Brabb do not show faulting, and west of section 32, T11S, R4E where Dibblee and Brabb extend traces of the Castro fault and north branch Sargent fault. Near the northern border of section 32, T11S, R4E, traces of the Castro fault and north branch Sargent fault are shown to merge (figure 2b). The trend of this merged fault

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trace is more southerly until it reaches the northern slope of Lomerias Muertas where historically active, massive landslides obscure traces of the Sargent fault zone (figure 2b).

The north branch Sargent fault is shown by Dibblee and Brabb as a single trace (figure 2b). They do not show the fault trace mapped by Allen (1946) and Bishop (unpublished) in section 25, T11S, R3E (figure 2b). Interpretation of air photos by this writer indicates that geomorphic evidence does not support the existence of a single, continuous trace of the north branch Sargent fault (figure 3b).

The north branch Sargent fault southeast of the NW 1/4 of section 32 is shown as concealed by Dibblee and Brabb (figure 2b). Herd (p.c., December 1979) and Smith (1980) located the trace about 500 feet to the southwest along the base of a linear ridge trending diagonally across section 32, T11S, R4E. Herd interprets the linear ridge as an eroded fault scarp and considers this fault trace to be recently active (figure 3b). The ridge seems to be a fault-line scarp modified by erosion, based on interpretation of air photos by this writer (figure 3b).

Bishop (unpublished) mapped a segment of the Sargent fault zone from near Pescadero Creek southeast to the eastern border of the Chittenden quadrangle (figure 2b). The trend of Bishop's south branch Sargent fault is similar to the traces of Allen (1946) and Dibblee and Brabb (1978), but Bishop's north branch Sargent fault extends more to the north and east (figure 2b). Segments of Bishop's north branch Sargent fault were verified locally by this writer, based on air photo interpretation, but geomorphic evidence does not support the extension and continuity of the fault traces shown by Bishop (figure 2b, 3b).

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Brown (1970) shows traces of the Sargent fault zone thought to be historically active or to have had geologically young surface displacement. The location of fault traces was based on interpretation of 1:80,000-scale air photos. These traces, which were not field checked by Brown, were plotted on 1:250,000-scale base maps. The scale of the base map is too small to be critically considered for evaluation in this report.

Armstrong (1980) mapped a portion of the south branch Sargent fault from Tar Creek southeast to the Pajaro River (figure 2b). Armstrong shows the south branch Sargent fault to be offset in an apparent left-lateral sense by north-east-trending faults (figure 2b). These faults display geomorphic features in Pliocene bedrock, but there is no evidence to suggest Holocene faulting.

Traces of the Sargent fault zone in the easternmost Lomeras Muertas and in the Flint Hills are characterized by faulting with components of both vertical (extensional) and right-lateral strike-slip displacement. Part of the vertical component of offset may be due to both small and large scale gravity adjustments, but tectonic faulting cannot be dismissed. The location of the Sargent fault zone between the Calaveras and San Andreas fault zones implies that a complex pattern of stress occurs along the Sargent fault zone, especially as the Sargent fault nears the Calaveras fault. The extensional nature of the offset along the southeastern most segment of the fault zone in the Flint Hills may be due in part to a wrenching style of deformation (Wilcox and others, 1973) in response to movement along the Calaveras and San Andreas fault zones.

Rogers (in press) mapped the Sargent fault zone on the San Felipe 7.5-minute quadrangle (figure 2c). Fault traces on the southwestern portion of the map are characterized by a significant vertical component of offset and trend sub-parallel with the Calaveras fault, which is located about 2.5 miles

to the east. A fault trace along the south side of a distinctive west-northwest trending group of hills is shown by Rogers as cutting Plio-Pleistocene San Benito Formation (equivalent to Santa Clara Formation) but not late Pleistocene to Holocene alluvium (figure 2c, 3c).

Traces of the Sargent fault zone mapped by Dibblee (1975) are in the general vicinity of traces mapped by Rogers. However, Dibblee doesn't show a fault along the northeast portion of the Flint Hills where Rogers does (figure 2c). The distinct change in topography defining this west-northwest trending group of hills about 1/2 mile south of Hudner is thought by Herd (p.c., 1979) to be controlled by bedding in the San Benito (Santa Clara) Formation (strike ridges). Rogers shows the axis of an anticline along the crest of the ridges, but projects this structure based on an insufficient number of bedding attitudes.

Geomorphic evidence of fault traces along portions of the north slope of Lomerias Muertas is obscured or concealed by Holocene and historic landsliding (figure 3b). Landsliding is less intense toward the east in the San Felipe quadrangle and through-going fault features can be identified with more certainty (figure 3c). Traces of the Sargent fault zone in the easternmost Lomerias Muertas and in the Flint Hills are characterized by geomorphic features indicating Holocene right-lateral and vertical faulting. Geomorphic evidence for Holocene <sup>(primarily extensional)</sup> faulting, based on air photo interpretation by Smith (1980) and this writer, includes well-defined scarps and sidehill benches in bedrock and alluvial deposits of late Pleistocene and Holocene age, closed depressions, tonal lineaments in alluvium, grabens, and linear valleys (figure 3b, 3c). Less well-defined geomorphic evidence suggesting right-lateral offset includes right-laterally deflected drainages and right-laterally offset ridges.

Historic surface displacement on the Sargent fault zone is implied by results of geodimeter surveys by California Department of Water Resources (CDWR, 1968). Geodimeter lines across the San Andreas and Sargent faults up to 16 1/2 miles (27km) long were periodically measured from 1960 to 1964. An average rate of movement on lines 17 and 18 was 3.4 cm/year and 1.5 cm/year, respectively, in a right-lateral sense (i.e. both lines were shortening) (figure 1). Line 18 does not cross the Sargent fault and it was assumed that movement along the Sargent fault accounted for the <sup>discrepancy</sup> ~~discrepancy~~ of shortening along lines 17 and 18 (DWR, 1968). However, movement along the Sargent fault was not conclusively proven because movement vectors were not exactly parallel to the fault. In addition, the precise location of creeping strands is not possible to determine at the scale of this survey.

Prescott and Burford (1976) found evidence for right-lateral fault creep on the Sargent fault about 4500 feet southeast of Whitehurst Road (figure 3a). An alignment array surveyed periodically during 1970-1975 showed right-lateral fault creep with an average displacement rate of about 3mm/year (0.12 inch/year). Two discrete zones of displacement about 130 feet apart coincide very well with geomorphic features defining two fault traces (figure 3a, 4). Results of repeated surveys of a nearby trilateration network (fault creep rate  $3.5\text{mm} \pm 1.2\text{mm}/\text{year}$ ) agree well with the measurements of the alignment array ( $2.9\text{mm} \pm 0.7\text{mm}/\text{year}$ ), thus indicating that displacements are due principally to fault creep rather than other, non-tectonic influences. An additional alignment array in the northwest corner of section 26, T11S, R3E was periodically resurveyed from 1969 to 1975 (figure 2b). The alignment array was placed in a relatively poor location and results of repeated surveys generally show gravity creep (Burford, p.c., 1979). Geodimeter lines in northern Hollister

Valley cross traces of the Sargent fault in the Flint Hills. Interpretation of these lines by J. Savage (USGS) indicates that fault creep is occurring along the Sargent fault zone at the rate of 4mm/year (Burford, p.c., 1979).

However, specific traces of the Sargent fault cannot be associated with this fault creep rate due to the length of the geodimeter lines.

Locations of earthquake epicenters define a segment of the Sargent fault zone very well (figure 5) (Real and others, 1978). A change in the trend of epicenters coincides with the location and trend of the north branch of the Sargent fault (figure 5). The seismicity pattern indicates that historic earthquake activity shifts from the Sargent fault to the north branch Sargent fault in the west-central portion of the Chittenden quadrangle. Preliminary first motion studies of earthquakes along the southeast segment of the Sargent fault indicate that fault displacement is right-lateral strike-slip (W.H.K. Lee, p.c., 1980).

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## 6. Conclusions

The Sargent fault zone is a complex and wide zone of interconnecting faults, apparently resulting from right-lateral movement along the San Andreas fault system. A complex history of predominantly reverse faulting (southwest side up) has occurred along the Sargent fault zone to the northwest of the study area, and stratigraphic relationships indicate that reverse faulting has occurred in the past (post-Miocene and pre-late Pleistocene?) in the study area. At the very southeastern end of the Sargent fault zone in the San Felipe quadrangle, evidence for both vertical and right-lateral offset can be observed.

Although the Sargent fault zone is more than a mile wide, individual fault strands are well-defined by strong lithologic contrasts and differential erosion. Evidence of Holocene activity primarily is indirect and confined to geomorphic features (linear depressions, sidehill benches, scarps) developed principally on pre-Holocene rocks. However, systematic right-lateral offset of drainages is only weakly developed, suggesting either a low rate of Holocene right-lateral displacement along some segments, or a significant vertical component of offset, possibly during late Pleistocene - early Holocene time. Erosion and slope instability (landsliding and possibly others large-scale gravity adjustments) seem to be significant factors in obscuring small-scale ("micro") geomorphic features indicative of Holocene faulting. Nonetheless, historic right-lateral displacement has been measured along a well-defined trace of the Sargent fault in the Watsonville East quadrangle and several traces coincide rather closely with a zone of well-located earthquake epicenters.

#### A. SARGENT FAULT

1. The segment of the Sargent fault from Hecker Pass Highway southeast to the north-south trending power lines does not display direct evidence of Holocene faulting (see *Figure 3a*, this report, figure 3a). Geomorphic evidence for Holocene faulting is very weak and is expressed primarily as a somewhat linear valley and associated southwest-facing scarp. Tertiary sedimentary rocks are juxtaposed against Franciscan Formation at this location (Dibblee and Brabb, 1978; this report, figure 3a).

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2. Traces of the Sargent fault from the north-south power lines southeast to the east edge of the Watsonville East quadrangle locally display evidence permissive of Holocene faulting. Geomorphic evidence of Holocene faulting is not strong along the segment of the fault, probably because: 1) Holocene deposits are very sparse and are usually restricted to streambeds that are actively being eroded, and 2) Holocene surfaces are continually being modified by erosion and downhill movement. Geomorphic features indicating Holocene surface faulting include scarps and benches in Tertiary and Mesozoic bedrock, linear drainages, and "hanging valleys" (McLaughlin, 1971; Smith 1980; this report, figure 3a). Historic fault creep (3mm/year, Prescott and Burford, 1976) has been documented and is associated with two parallel fault traces mapped by Allen (1946), Dibblee and Brabb (1978), and this writer (figure 2a, 3a). The close association of earthquake epicenter locations in this area (Real and others, 1978; figure 5) suggests recent activity, but precise locations of fault traces for about 7000 feet southeast of the USGS alignment array (figure 3a) have not been verified.

3. The south branch Sargent fault displays geomorphic evidence of recent right-lateral faulting for about 3000 feet at the western edge of the Chittenden quadrangle (figure 3b). There is no evidence of recent faulting on the south branch Sargent fault from about section 26, T11S, R3E southeast to Highway 101. Lithologic evidence east of Highway 101 indicates that the south branch Sargent merges (Dibblee and Brabb, 1978) with the recently active north branch Sargent fault

(figure 2b). However, geomorphic evidence of recent faulting was not observed along this segment of the south branch Sargent fault (figure 3b).

4. The north branch Sargent fault displays geomorphic evidence of Holocene faulting such-as right-laterally offset ridges, beheaded drainages, scarps, linear troughs, linear valleys, and closed depressions (Allen, 1946; figure 3b, this report). The change in trend of earthquake epicenters corresponds well with the trend of the north branch Sargent fault (Real and others, 1978; figure 5). First-motion studies of earthquakes along the trend of the Sargent fault on the segments described in parts 2 and 4 of the conclusions section indicate right-lateral strike-slip displacement (Lee, p.c., 1980). These first-motion studies further support the geomorphic evidence indicating right-lateral faulting.

The north branch Sargent fault from the SE 1/4 of section 30, T11S, R4E southeast to the Pajaro River is expressed by discontinuous linear features suggestive of recent faulting. Geomorphic evidence includes scarps in Holocene alluvium and Pleistocene deposits, and right-laterally deflected drainages. A strong tonal lineament is associated with a modified, subtle northeast-facing scarp in Holocene deposits just east of the Pajaro River (Smith, 1980; figure 3b). Geomorphic evidence for recent faulting extends only for about 1000 feet into Lomerias Muertas (figure 3b).

5. The Sargent fault southeast of Lomerias Muertas is expressed by discontinuous, but locally well-defined curvilinear fault traces displaying evidence of extensional and right-lateral strike-slip

faulting. The north slope of Lomerias Muertas is characterized by complex shallow and deep landslides. Lateral-spreading may be the cause of some of the features observed in the Flint Hills, but tectonic faulting cannot be dismissed. Herd (p.c., 1979) and Smith (1980) feel that Holocene surface faulting is expressed locally, such as by faulting across Holocene landslide deposits and by recent geomorphic features such as closed depressions (sag ponds), bench on alluvial fan, scarps in alluvium, tonal lineament in alluvial fan, and grabens (figure 3c).

B. CASTRO FAULT

The Castro fault is expressed in Mesozoic bedrock from Hecker Pass Highway southeast to Castro Valley. McLaughlin (1973; p.c., 1979) found undisturbed upper Pleistocene terrace deposits along the trace of the Castro fault near Whitehurst Road (figure 2a). No evidence of recent faulting could be found along the trace of the Castro fault northwest of Castro Valley, except for an air photo lineament in the location where Allen (1946) reported a 10-foot high scarp in a saddle, north side down. The photo lineament, about 1000 feet long, is subtle and was not field checked.

The Castro fault from the Castro Valley area southeast to NE 1/4 section 25, T11S, R4E is expressed by tonal lineaments, low scarps, and springs (Herd, p.c., 1979, Smith, 1980) (figure 3b). The alluvium in the valley is considered to be Holocene in the northwest portion of the Castro Valley and late Pleistocene along the southeast trend of the valley (Dibblee and Brabb, 1978). According to Herd (p.c., 1979), the association of seismic activity (Real and others,

1978; figure 5, this report) with recent fault features indicates Holocene faulting (Herd, p.c., 1979).

7. Recommendations (numbers correspond with fault segments under Conclusions)

Recommendations for zoning faults for special studies are based on the criteria of sufficiently active and well-defined (Hart, 1980).

A. SARGENT FAULT

1. Zone for special studies traces of the Sargent fault shown on figure 6a, based on Dibblee and Brabb (1978) and this report. The recommendation for zoning is based on the association of a linear drainage and modified southwest-facing scarp with fault features farther southwest that locally display evidence of Holocene faulting.
2. Zone for special studies traces of the Sargent fault shown on figure 6a, based on Dibblee and Brabb (1978), McLaughlin (1971), Smith (1980), and this report. Recommendation based on survey data of Prescott and Burford (1976) that shows fault creep of 3mm/year, and locally well-defined fault traces.
3. Do not zone south branch Sargent fault. Fault trace is not sufficiently active, based on undisturbed Pleistocene terrace deposits (Allen, 1946), and the fault segment is not well-defined.
4. Zone for special studies traces of the north branch Sargent fault shown on figure 6b, based on Dibblee and Brabb (1978), Smith (1980), and this report. Well-defined fault traces are located in the SW 1/4 of section 23, center of section 25, and E 1/2 of section 30.
5. Zone for special studies traces of the Sargent fault shown on figures 6b and 6c, based on Dibblee (1975), Rogers (in press), Smith (1980), and this report. Recommendation to zone based on sufficiently active and well-defined fault traces in the Flint Hills.

Locally well-defined, but very discontinuous fault traces can be followed through complex, massive landslides along the north slope of Lomerias Muertas.

B. CASTRO FAULT

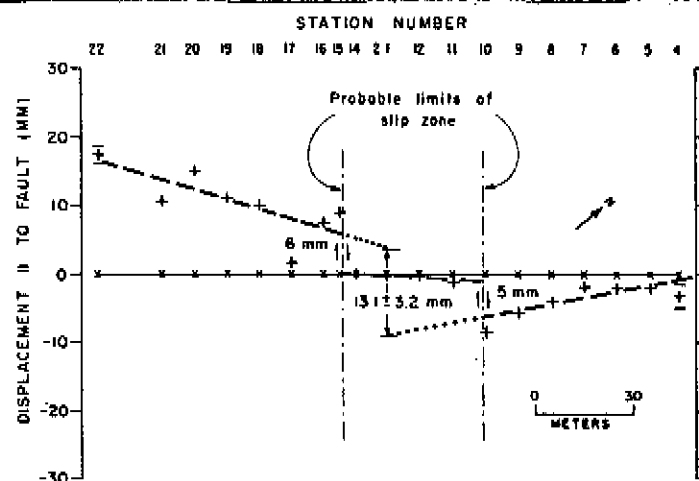
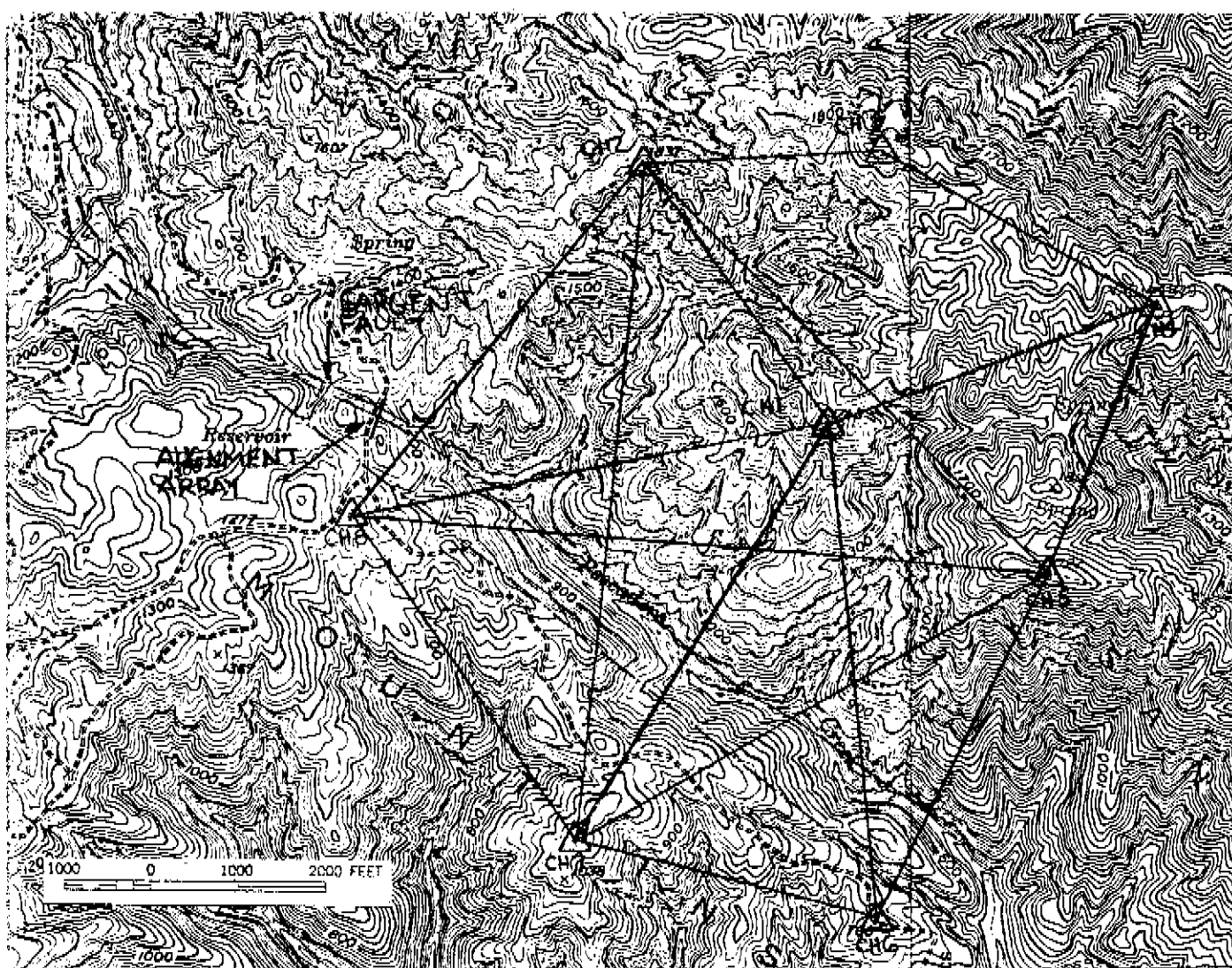
Zone for special studies the segment of the Castro fault shown on figure 6b, based on well-defined fault traces of Smith (1980) and this report.

Do not zone traces of the Castro fault northwest of Wildcat Canyon. Castro fault does not offset Pleistocene-age terrace deposits located about 2000 feet southeast of Highway 152 (figure 3a).

8. Report prepared by William A. Bryant, December 11, 1980.

*William A. Bryant*

*I concur with  
the recommendations:  
EAB  
12/24/80*



Comparison of observation 2 and observation 3 of Chase alignment array. The configuration of the stations at the time of observation 2 is used as a reference and is plotted as a straight line perpendicular to the fault. The relative motion given by comparison of the two observations is then plotted as a deviation from this line. The dashed lines are least-squares fits to the data and the dotted lines indicate the projection of these lines to station 1.

Figure 4 (to FER 96). Comparison of surveys of Chase alignment array, showing fault creep displacements that average  $2.9 \pm 0.7$  mm/year over the period 1970 to 1975. Also shown are locations of alignment array and trilateration network in relation to Sargent fault (Prescott and Burford, 1976).